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# Environmental Assessment Approaches to Foster the Implementation of Cleaner Production Strategies in Vietnamese Aggregates Mining

**Petra Schneider[a], Klaus-Dieter Oswald[b], Wolfgang Riedel[b], Andreas Meyer[a]**

*[a] University of Applied Sciences Magdeburg-Stendal, Breitscheidstr. 2, D-39114 Magdeburg, Germany; petra.schneider@hs-magdeburg.de*
*[b] C&E Consulting und Engineering GmbH, Jagdschänkenstr. 52, D-09117 Chemnitz, Germany; Klaus-dieter.oswald@cue-chemnitz.de, wolfgangriesa@gmail.com*

**Abstract**

Cleaner Production (CP) addresses precautionary, site specific environmental measures for the reduction of waste and wastewater emissions at the point of origin by analyzing the operational material and energy flow for the initiation of improvements in industrial processes. The approach is generally based on the criteria quality, environment as well as occupational health and safety, as specified in ISO 9001 and 14001, and promotes the integration between them. The contribution presents the possibilities of CP approaches in the mining industry, also taking into account also the Life Cycle Assessment (LCA) according to ISO 14040, and discusses the differences to the conventional Environmental Impact Assessment (EIA) and other environmental assessment methodologies.

The application areas of cleaner production approaches in the mining industry are illustrated with examples from the aggregates mining in Hoa Binh province, Vietnam. Even the EIA methodology is quite well established in Vietnam as environmental assessment procedure, in the Hoa Binh Regional Planning has not been prepared yet a strategic environmental assessment for mining operations and construction materials production. There are comprehensive environmental monitoring programs implemented at the aggregates companies in Hoa Binh, as required by the environmental regulation. The regulatory framework is generally comparable to the international standard, this concerns also the enforcement of the regulation which is supported by environmental monitoring programs and inspections. Apart from the stepwise collection of long term experiences with the practical handling of the enforcement procedures, there is a large optimization potential for CP strategies in the Vietnamese aggregates mining. This can be concluded from the results of a questionnaire survey carried out in aggregates mining companies in Hoa Binh province in order to determine the technological characteristics of the production sites, as well as the economic and ecological background. The assessment of the survey is supported by preliminary LCA results.

*Key Words: environmental assessment, cleaner production, aggregates mining*

## 1. Introduction

Cleaner Production (CP), a philosophy for environmental protection in the manufacturing and services sector, adopted by the United Nations under the United Nations Environment Program (UNEP), is a process that integrates the entire production-integrated environmental protection of a process chain, regardless of the sector (UNEP, 2006). The Cleaner Production Concepts (CPC) were formulated at the 1992 UN Conference on Environment and Development in Rio de Janeiro.

The basis of CPC is a sustainable, integrated and systematic environmental protection strategy that focuses on processes, products and services alike. CP refers to precautionary, company-specific environmental protection, in which waste, wastewater and emissions are tracked to their place of origin by means of the analysis of operational material and energy flows, thereby developing approaches for internal improvement measures in industrial processes. Anyhow, environmental compliance starts already much earlier, and has to cover the exploration application for the mining operation through Environmental Impact Assessment (EIA).

Scope of this study is to present the available environmental assessment approaches to foster the implementation of CP strategies in the mining sector. While environmental protection in the mining sector plays already a significant role in industrialized countries, CP approaches in emerging markets have so far not been applied systematically in mining. The paper presents the possibilities of CP approaches in the aggregates mining industry, illustrated with examples from Hoa Binh province in Vietnam.

## 2. Approaches to Environmental Assessment

### *2.1. Overview*

Environmental assessment is a methodology that ensures that environmental effects of decisions are taken into account before the decisions are made. Different environmental assessment approaches are applied in practice, depending if the environmental implications of a plan, project or product shall be considered. Figure 1 gives a general overview on the existing environmental assessment approaches with respect to mining, which will be discussed in further detail hereafter.


Figure 1. Overview on the existing environmental assessment approaches with respect to mining.

### *2.2. Strategic Environmental Assessment (SEA)*

SEA is a legal instrument for the environmental assessment of plans and programs. With SEA, potential environmental impacts of a planning can be recognized and taken into account before the plan or program is accepted. Typical applications are regional development plans, land use plans, waste management plans, energy concepts, etc. In the European Union, SEA is based on the EC Directive (2001/42/EC) on the assessment of the environmental effects of certain plans and programs.

In the mining sector, SEA plays a major role in regional planning, as reserve areas and priority areas for mining are identified as a result of the localization of ores and mineral resources. In this regard, SEA supplements the Environmental Impact Assessment (EIA). The main difference is that SEA start earlier than EIA. While the EIA is used for the approval of environmentally relevant projects, SEA is already carried out at the regional planning stage.

### *2.3. Environmental Impact Assessment (EIA)*

EIA is an environmental policy instrument of environmental protection with the aim of verifying environmentally relevant projects prior to their approval for possible environmental impacts. As a rule, it is limited to verifying the impact on environmental factors. Economic and social consequences are not part of EIA. Practically, EIA is an environmental assessment report on how a project can affect environmental factors, like people (including human health), animals, plants, biodiversity, soil, water, air, climate, landscape and cultural heritage. The report is open to the public, the involved authorities, and other stakeholders, including neighboring countries (if applicable). Generally, EIA is regulated in the respective national environmental regulations. Further, at the scale of the European Union applies the EIA-Directive 2011/92/EU.

### *2.4. Environmental Management Systems (EMS)*

An EMS is that part of the overall overarching management system, which includes the organizational structure, responsibilities, formal procedures, and means for the implementation of the environmental policy of a company. ISO 14001:2015 specifies the conditions for an EMS that an organization can use to enhance its environmental performance.

An environmental management system basically includes 1) the environmental policy, 2) objectives and programs, 3) organization and personnel, 4) impact on the environment, 5) design and process control, 6) environmental management documentation, 7) environmental audits. On international scale the most common standardized EMS is provided by ISO 14001:2015. In the European Union further exists the “EU Eco-Management and Audit Scheme” (EMAS), a premium management instrument developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance.

### *2.5. Life Cycle Assessment (LCA)*

LCA is a systematic analysis of environmental effects of products throughout the life cycle. The preparation procedure is laid down in ISO 14040:2006. LCA includes all environmental effects during the production, the utilization phase and the disposal of the product, as well as the associated upstream and downstream processes (e.g. production of the raw materials and supplies). Environmental impacts are classified in impact categories and include all environmentally relevant withdrawals from the environment (e.g. ores, petroleum) and emissions into the environment (e.g. waste,

$CO_2$ emissions). The overall scope of the assessment is to find environmental optimization potential in order to achieve a cradle-to-cradle system (Braungart & McDonough, 2002).

According to the International Organization for Standardization (ISO), LCA comprises the steps: 1) definition of goal and scope (ISO 14040), 2) Life Cycle Inventory Analysis (LCI) with definition of the functional unit (ISO 14041), 3) Life Cycle Impact Assessment (LCIA) (ISO 14042), and 4) Life Cycle interpretation (ISO 14043). The interpretations phase should deliver results that are consistent with the defined goal and which reach conclusions, explain limitations and provide recommendations. LCA is used for eco-design, strategic planning, environmental product declaration (ecolabels), policy making and marketing.

### *2.6. Environmental Monitoring (EM)*

EM refers to the observation of scientifically relevant areas of the environment and the documentation of ecological parameters. The scientific fields include biology, soil science, chemistry, geography, geology, hydrology, meteorology and physics. The findings can be important for forestry, landscape planning and other environmentally relevant planning tasks and problems, as well as the scientific monitoring of environmental projects. The goal is the long-term recording of environmental and environmental protection-relevant changes in air, soil and water. Impacts on landscape and biodiversity can thus be systematically recorded.

In terms of the implementation of CP strategies in the mining sector, EM plays a role in all design and operational steps. An EM plan needs to be provided by the applicant for the respective EIA project, and will be complemented by an obligatory EM plan through the mine approval by the authority.

## 3. Methodology

Vietnam is currently facing an extraordinary construction boom. This leads to growing environmental problems related to the mining of construction materials, especially a) in the Hanoi capital region, and b) to conflicts regarding land consumption in the surrounding area of Hoa Binh province, where agricultural land and settlements are particularly affected. The interest in appropriate CP guidelines for the aggregates mining sector is high. A significant problem is the small-scale nature of Vietnamese aggregates mining, which, while respecting the classic work and environmental protection measures, reaches its limits with regard to resource efficiency.

Within the framework of the MAREX project and in order to determine the technological characteristics of the production sites, as well as the economic and ecological background, a questionnaire survey was carried out in selected Vietnamese aggregates mining companies in Hoa Binh province. By August 2016, 27 completed questionnaires were submitted by the Vietnamese mining companies. The questionnaire focused on the following:

1) Part 1: General Information

2) Part 2: Information on the mining companies

3) Part 3: Extraction and processing technology as well as material requirements

4) Part 4: Resource consumption and environmental aspects

5) Part 5: Occupational health and safety.

A field study trip was conducted in November 2016 to consider the situation of 12 of the 27 companies that answered the questionnaire. A special focus of the project was to collect information on the operational status, and which type of environmental assessment procedures are applied, to which extent, and which CP implementation and optimization options do exist.

## 4. Results: Application of Environmental Assessment in Aggregates Mining

### *4.1. Selected Survey Results*

Having as backbone the large reserves of limestone and clay, the production of building materials is one of the key industries of Hoa Binh province, providing building materials for the region and neighboring provinces. According to the results of the questionnaires,

| Excavation area | Number of companies | % |
|---|---|---|
| < 5 ha | 13 | 48.1 |
| between 5 and 10 ha | 6 | 22.2 |
| between 10 and 15 ha | 3 | 11.1 |
| between 15 and 20 ha | 4 | 14.8 |
| > 20 ha | 1 | 3.7 |

The size of the extraction areas is between 3 and 17.4 ha, the mean value being 7.3 ha. Of the surveyed sites, a maximum of 5 is medium-sized, the larger is small-scale enterprises and a large proportion is classified as micro-enterprises with an annual output of ≤ 40 Tm³. 65,4% of the companies have a mining license for a period more than 30 years.

Out of the 15 companies that reported their profit in 2015, 4 suffered losses. The average profit over all companies which provided information on this question is 1.4% of the total turnover. None of the companies received governmental grants. The average annual environmental tax of the companies (17 replies) is ≈ 266,000,000 VND (≈ 11,700 US $), with a span width of ≈ 21.862.000 VND (≈ 962 US $) to ≈ 852.000.000 VND (≈ US $ 37,500).

the extracted materials are clay (1) and limestone (23); no answer was given by 3 other companies. The total volume quarried by all companies is 1.96 mil t/a. Aggregates are mined exclusively in quarries. 44,4% of them are organized as Ltd. Company, 29,6% as Joint stock company, the rest have other organizational forms. The excavation amount to:

26 companies provided information on their main sales markets, with the following result:

- Ha Noi: 15
- Hoa Binh: 20
- Other: 4.

The average sales price for selling directly in the quarry is 80,000 VND/t (≈ 3.52 US $), with a price range of 45,000 VND/t (≈ 1.98 US $) to 113,000 VND/t (≈ 4 to 97 US $). Two companies provided data on the price for the delivery on site, both at 126,000 VND/t (≈ 5.54 US $). 6 companies gave information on average transport prices, which are very different. The resulting average transport price is approx. 4,700 VND/t (≈ 0,21 US $), with a clamping width from a free delivery up to ≈ 8,000 VND/t (≈ 0,35 US $).

### *4.2. Implementation of Environmental Regulations in Mining*

In Vietnam, aggregates production is governed by the Ministry of Natural Resources and the Environment, under following legal framework:

- No.: 45/2016/TT-BTNMT: Regulations on exploration of mineral resources and mining projects, as well as reports on mineral activities and the necessary documents contained in the application for authorization for mineral reserves and demolition procedures, amended on 26.12.2016 and
- No.: 26/2016/TT-BCT: Circular for the formulation, evaluation and approval of

mining investment projects as well as construction programs and cost estimates, as amended on 30.11.2016.

Within the framework of the mining legislation, the use of environmental technologies, the control of pollutant emissions, the establishment of a rehabilitation fund, the necessity to carry out EIA and the compatibility with certain environmental standards (Chapter IV, Article 30) are required. An authorization is required for the exploration of mineral resources and their extraction (Government Ordinance 76/2000 / ND-CP). The provisions of the Mining Law are supplemented by further regulations of the upper and lower administrative levels. Also regulated are the avoidance of environmental risks, the disposal of waste water and solid waste, pollu-tion control and subsequent rehabilitation.

### *4.2. Status of SEA and EIA in Vietnam with Respect to Regional Planning*

The "Construction master plan for Hanoi capital region to 2020, vision to 2050", covering the locations Hà Nội, Hà Tây, Vĩnh Phúc, Bắc Ninh, Hải Dương, Hueng Yên, Hòa Bình, Hà Nam (planning rea 13.436 ha), was approved in 2007 with the decision Số 490/QĐ-TTg ngày 5/5/2008. The "Construction master plan for Hoa Binh province region to 2020", covering an area of 14,784 ha, was approved in 2012 through the decision 1314/QĐ-UBND. Both documents foresee substantial construction activities.

In 1993, with the Decree 175/CP on Providing Guidance for the Implementation of the Law on Environmental Protection (LEP), general requirements for EIA were established (Clausen et. al. 2011). In the Circular 490/1998/TT-BKHCNMT on Guidance on Setting Up and Appraising the EIA Report for Investment Projects have been firstly laid down specific requirements for EIA. All surveyed companies have gone through a more or less complete EIA procedure for their approval. Since 2005, with the passing of the revised LEP (current version as of 2014), also SEA is mandatory for a range of national, regional and provincial strategies and plans. According to Minh (2016), in the Hoa Binh Regional Planning has not been prepared yet strategic environmental assessment for mining operations and construction materials production (air and soil pollution, biodiversity decrease, environmental disasters, etc.). It has to be considered that the small-scale industrial mining aggregates mining already started before the establishment of SEA as a regional planning tool. Two of the companies active in Hoa Binh province got their working permission before the SEA implementation in the legislation, having an excavation area of 16 and 9 ha. In the working permissions are also laid down the requirements for environmental monitoring, having a focus on dust protection.

### *4.3. Specific Results of the Questionnaire Survey with Regard to Environment*

The environmental standards, after which the companies are working, are: QCVN 05: 2013 / BTNMT, QCVN 6649: 2000 AA8800, TCVN 27: 2010 / BTNMT, TC.3733 / 2002 / QD.BYT, QVCN 27: 2010 / BTNMT, QCVN 08: 2008 / BTNMT, QCVN 14: 2008 / BTNMT, QCVN 19: 2009 / BTNMT and QCVN 40: 2011 / BTNMT.

74% of companies surveyed reported measures to reduce environmental impacts. The average dust load reported is 12.25 mg/m³ (7 answers), ranging from 0.27 to 33.6 mg/m³. The median is 9.9 mg/m³.

| **Reduction of Environmental Impacts** | **Number of companies** |
|---|---|
| Irrigation | 20 |
| Planting of trees | 11 |
| Mandatory use of modern equipment | 1 |
| Sedimentation ponds for processing sludge | 4 |

| | |
|---|---|
| Collection of wastewater | 3 |
| Recycling of industrial waste | 2 |
| Storage for hazardous waste | 1 |
| Small blasting works | 1 |
| No Information | 7 |

The information provided through the questionnaires implies that: (a) there is a general environmental awareness; and (b) safeguards are implemented, in particular where environmental impacts are small and/or directly affecting employees. 14 companies provided information on the waste generated. This applies to the following types of material (multiple entries possible):

- Waste water and solid waste
- Dust and stone wastes
- industrial waste.

The mean waste volume is about 430 m³/a, with ranging from 1.5 to 1,500 m³/y as well as a median of 194 m³/a. The amount of the processing residues was stated to be 1.9 t/a, ranging from 0.0015 to 18 t/y and a median of 0.03 t/a. No company indicated sludge as waste.

Appropriate measures to reduce energy consumption were found by the companies surveyed (14 replies):

- Economical use of raw materials
- Save energy and water
- Use of modern equipment, management of production output
- Regular maintenance of machines / machines
- Planning of production during the daily periods with low cost of electro-energy
- Save energy with respect to machines and equipment
- Efficient use of electricity and water, safe vehicles for transport
- Power saving - switch off the unit after use.

The following measures were named as further suitable measures to reduce the environmental impact (8 replies):

- Waste reduction at the source
- Reduction of waste of natural resources
- orderly storage of equipment and material.

At the moment, the main focus of the mining companies is on occupational health and safety (OHS). Environmental protection measures and environmental monitoring are implemented to the extent required by law, also due to the small revenues from a non-efficient operation.

The aggregates companies practice OHS measures, and usually have an internal OHS management system for a) the machines and equipment, as well as b) the operating activities. The measures include noise and vibration protection and dust reduction. 23 companies provided detailed information on noise protection measures, 16 on vibration protection measures. 24 companies provided detailed information on dust protection measures. In particular, the classical technical dust protection measures are applied such as sprinkler and irrigation systems, the covering or shielding of the dust source and the use of modern equipment. Regular health checks are also carried out. Measures for dust control are carried out in 89% of the companies. All companies provided information on the personal protective equipment (PPE) of employees. The following measures are used (multiple answers possible): protective helmets (92.5%), protective shoes (92.5%), protective gloves (92.5%), dust masks (92.5%), protective goggles (70.4%) and protective clothing (96.2%). Due to the fact that the majority of the companies is too small for a long term

economical efficient operation, budget for environmental protection measures is only allocated if a) required by law, or b) the measures are complementary with OHS measures, e.g. green belt for dust protection.

### *4.4. Environmental Management Systems (EMS)*

None of the companies has implemented an EMS according to ISO 14001:2015, even in other mining fields in Vietnam EMS' already exist.

### *4.5. Life Cycle Assessment (LCA)*

A LCA for the aggregates mining in Vietnam and its products does not yet exist, but it is an object within the MAREX project. The goal is to evaluate the optimization potential for the Vietnamese small-scale industrial mining industry. A LCA usually considers the environmental impact categories climate change, photochemical oxidation, cumulative energy demand, acidification, eutrophication, human toxicity and ecotoxicity, as well as abiotic resource depletion. Currently, are available preliminary results for the mineral extraction baseline assessment of the visited quarries. The functional unit is defined as a 1000 kg extracted minerals. For the purpose of comparison is considered also the quarry Ostrau in Germany, which represents an already optimized operating company. Figure 1 shows preliminary LCA results for the resource consumption of minerals (red) and water (blue). Figure 2 shows the climate change impact, expressed through the global warming potential ($CO_2$ equivalents and $CO_2$ emissions).

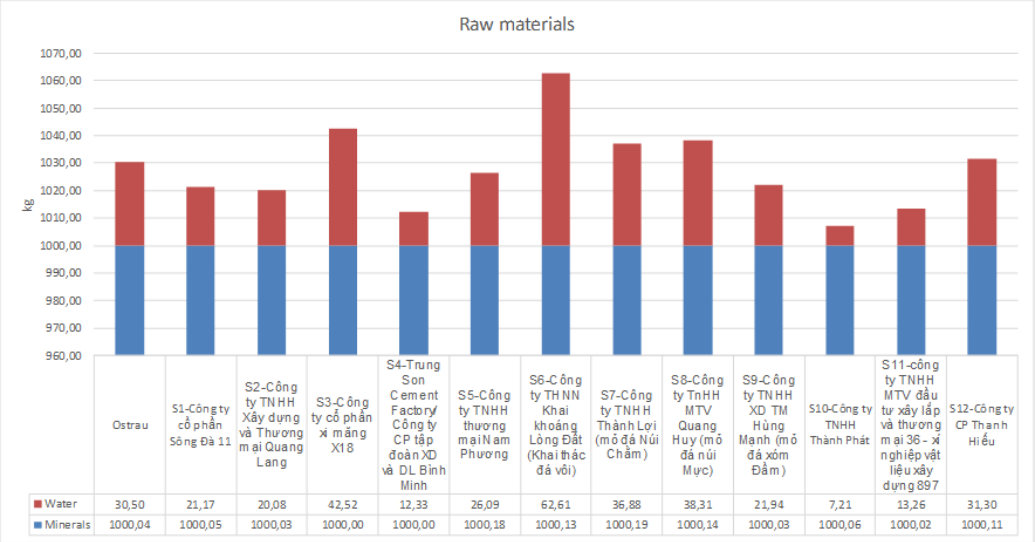


Figure 2. Resource consumption: minerals (red), water (blue).

Naturally, larger extraction activities cause larger environmental impacts. The calculation for further impact categories is under preparation.

### *4.6. Environmental Monitoring*

There are environmental monitoring programs implemented at the aggregates companies in Hoa Binh, as required by the environmental regulation. The monitoring considers criteria for the assessment of microclimate (temperature, humidity, wind direction and speed, precipitation), air quality (TSP, CO, $NO_2$, $SO_2$) and noise ($L_{eq}$, $L_{max}$), and water quality (temperature, pH, Chemical Oxygen Demand DOD, Biochemical Oxygen Demand BOD5, Hg, Cd, As, Pb, coliforms, and Total Grease). Official monitoring requirements regarding the soil do not exist yet. Exemplarily are investigated in the frame of the MAREX project soil mechanical and soil chemical parameters in order to assess their significance.

## 5. Conclusions

So far, there is no systematic use of CP approaches in the aggregates mining sector in Vietnam, although some of the relevant flows are collected during operation. Particularly at the level of small-scale industrial mining, there are extensive implementation CP potentials.

One scope of the MAREX project is to develop a "good mining practice" as a guideline for sustainable mining in this context.

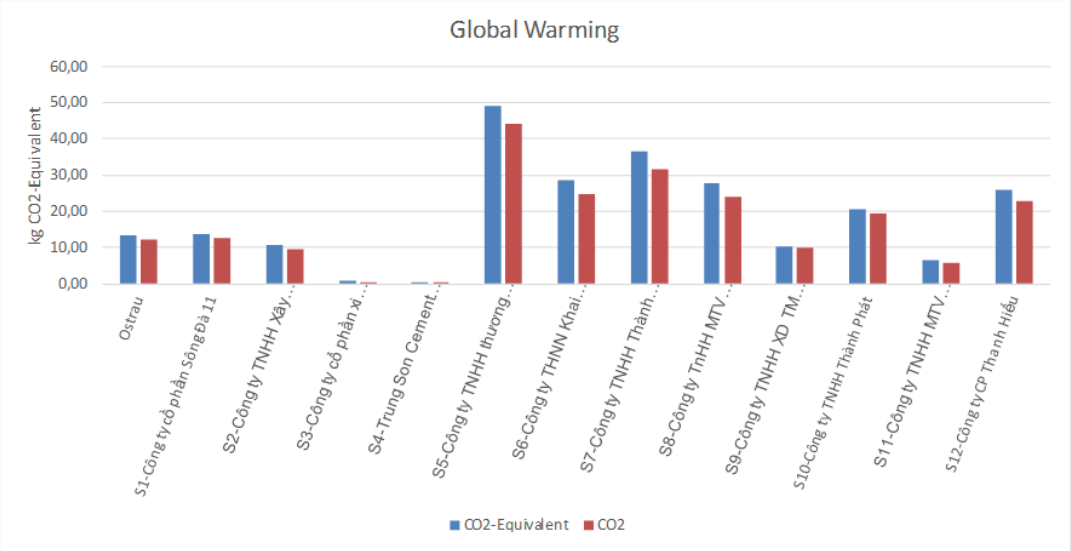


Figure 3. Global warming potential: $CO_2$ equivalents (blue), $CO_2$ emissions (red).

Mining can become more environmentally friendly through the development and integration of practices and techniques that reduce the environmental impact. These practices include measures such as reducing water and energy consumption, reducing land degradation and waste production, avoiding soil, water and air pollution (Hilson, 2000), the integration of Industrial Ecology Thinking into the management of mining waste (Lèbre & Corder, 2015) as well as carrying out successful closure and rehabilitation activities after the end of mining.

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**Corresponding author:**
*Prof.Dr Petra Schneider*

*University of Applied Sciences Magdeburg-Stendal, Breitscheidstr. 2, D-39114 Magdeburg, Germany;*
*Email: petra.schneider@hs-magdeburg.de*